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Finn et al.

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(54) **APPARATUS AND METHOD FOR SUPPORTING A STEEL CATENARY RISER**

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E21B 17/01 (2006.01)

(52) **U.S. Cl.** **405/224.3**; 405/224.2

(58) **Field of Classification Search** 405/224, 405/224.2–224.4, 223.1; 166/345, 350, 359, 166/367

See application file for complete search history.

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(57) **ABSTRACT**

An apparatus for supporting a steel catenary riser (SCR) from a floating structure having a keel includes a flexible support tube or keel sleeve through which the SCR passes. The support tube or keel sleeve includes a pivot mechanism that is lockably received in a receptacle fixed to the floating structure. A method of supporting an SCR from a floating structure includes the steps of inserting a first end of the SCR into a support tube or keel sleeve; fixing the support tube or keel sleeve to the SCR; pulling the support tube or keel sleeve into a receptacle fixed to the floating structure; releasing the support tube or keel sleeve from the SCR; pulling the SCR through the support tube or keel sleeve up to an attachment point on the structure; fixing the SCR to the structure; and fixing the support tube or keel sleeve to the SCR.

20 Claims, 9 Drawing Sheets

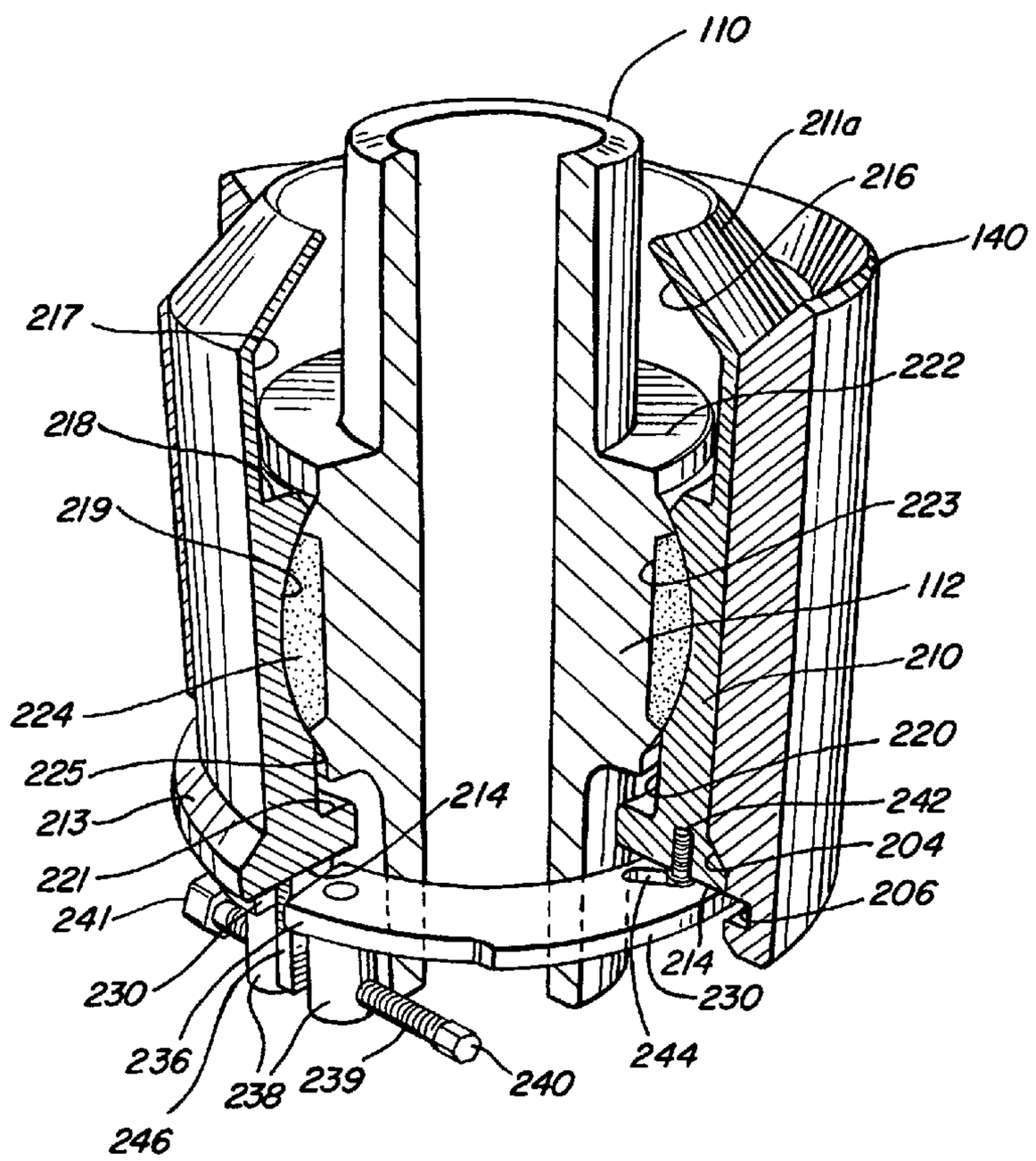
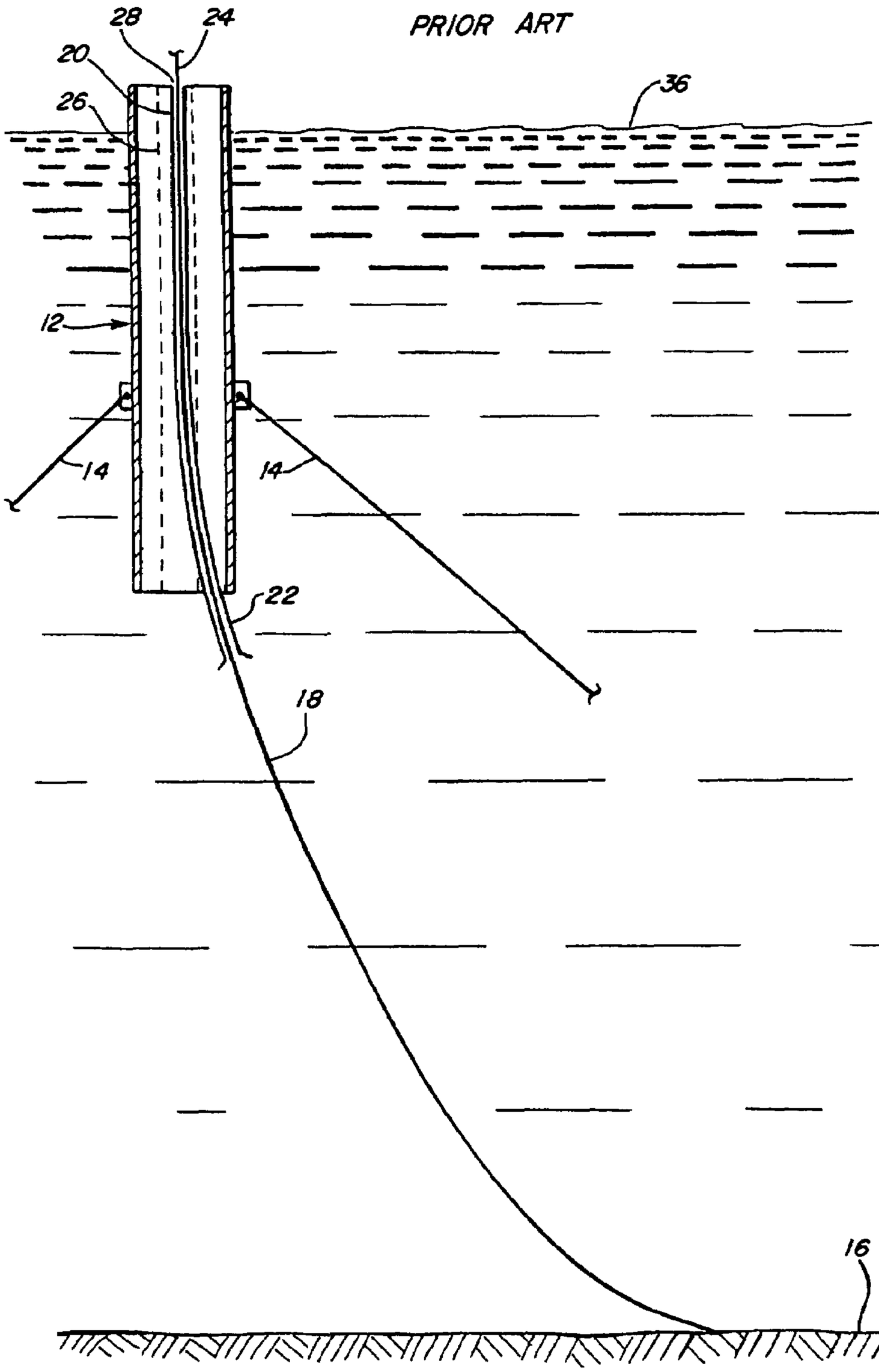


FIG. 1
PRIOR ART



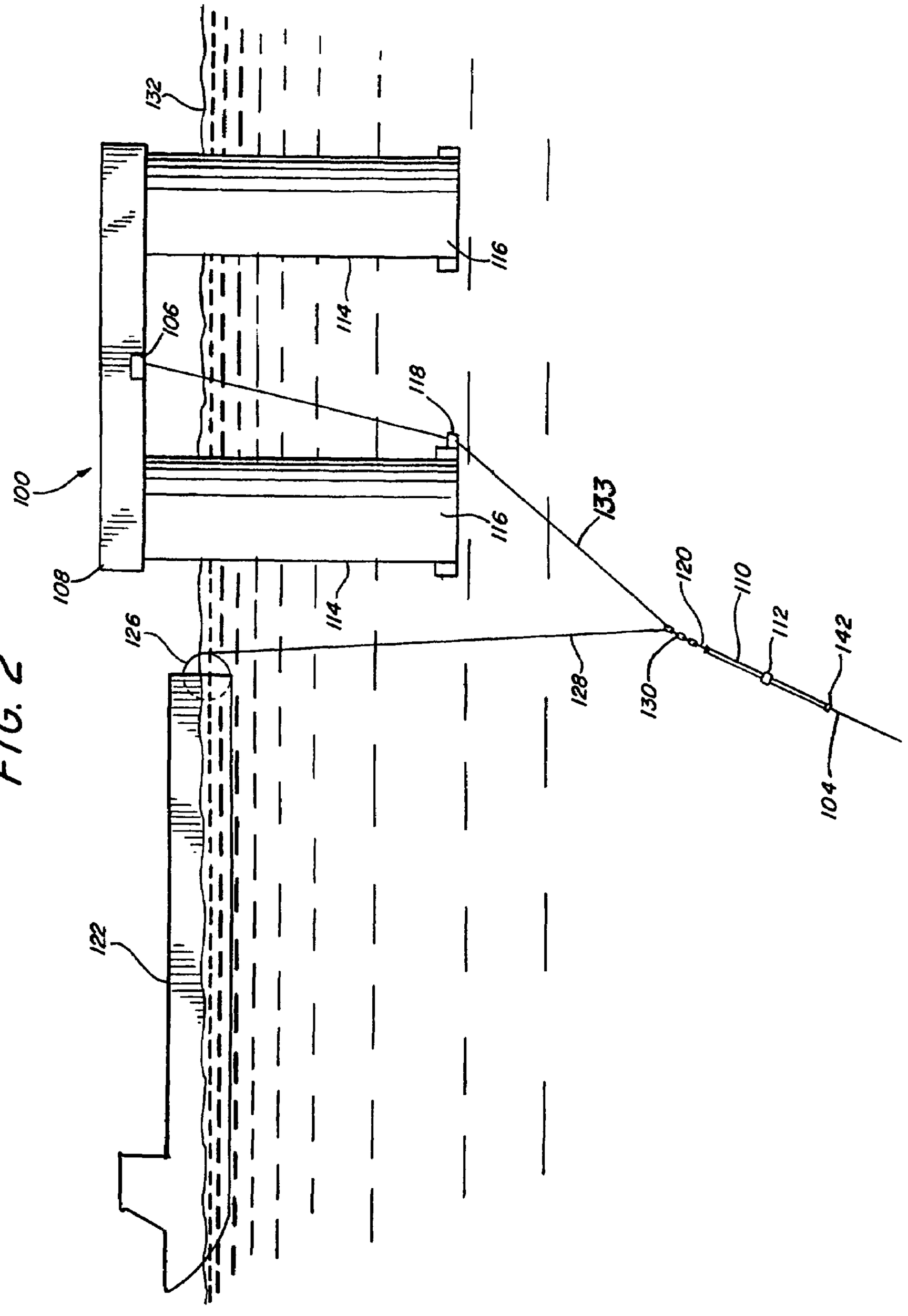

132
116
114
106
118
100
116
133
108
114
120
110
126
112
142
128
130
104
122

FIG. 2

FIG. 3

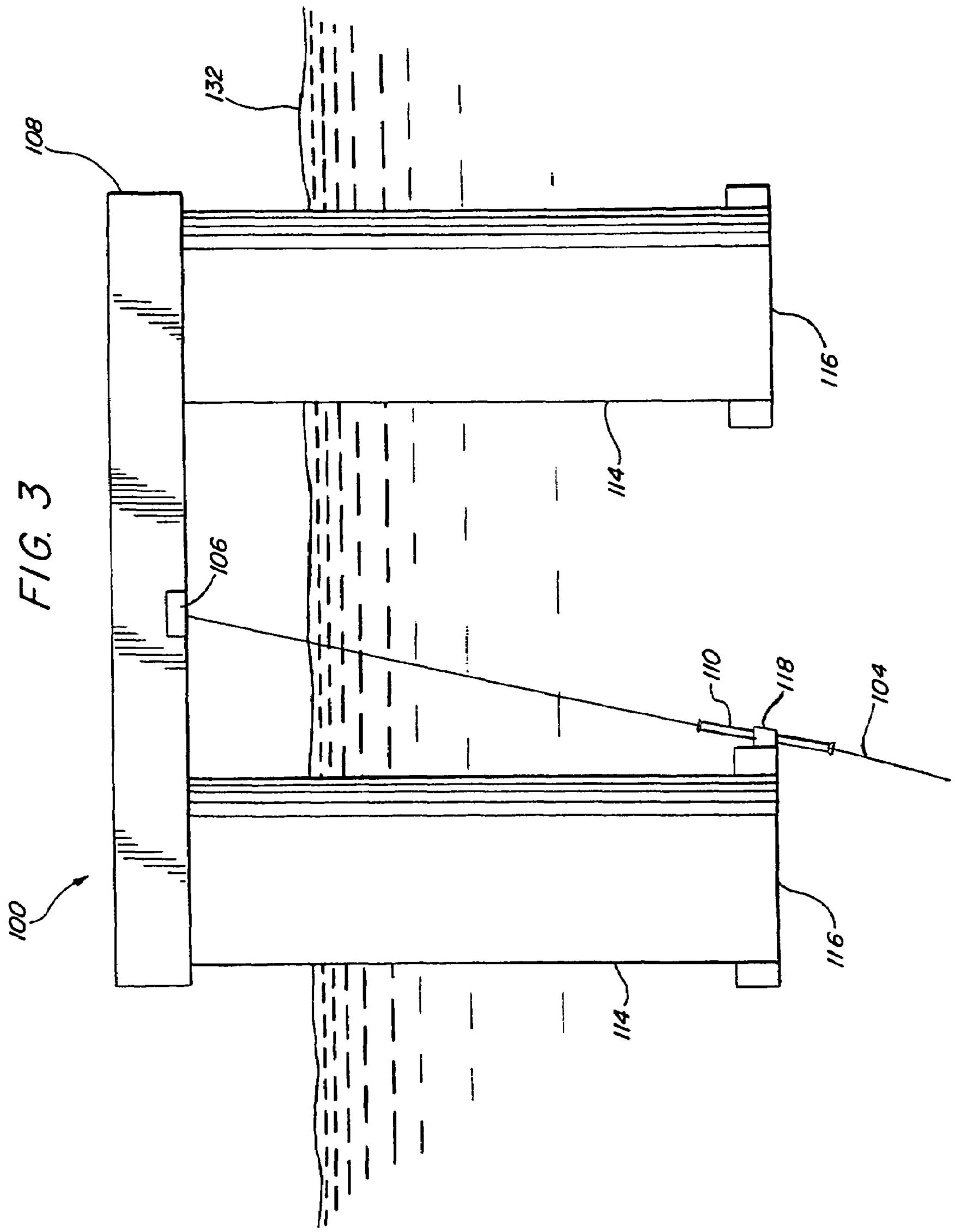


FIG. 4

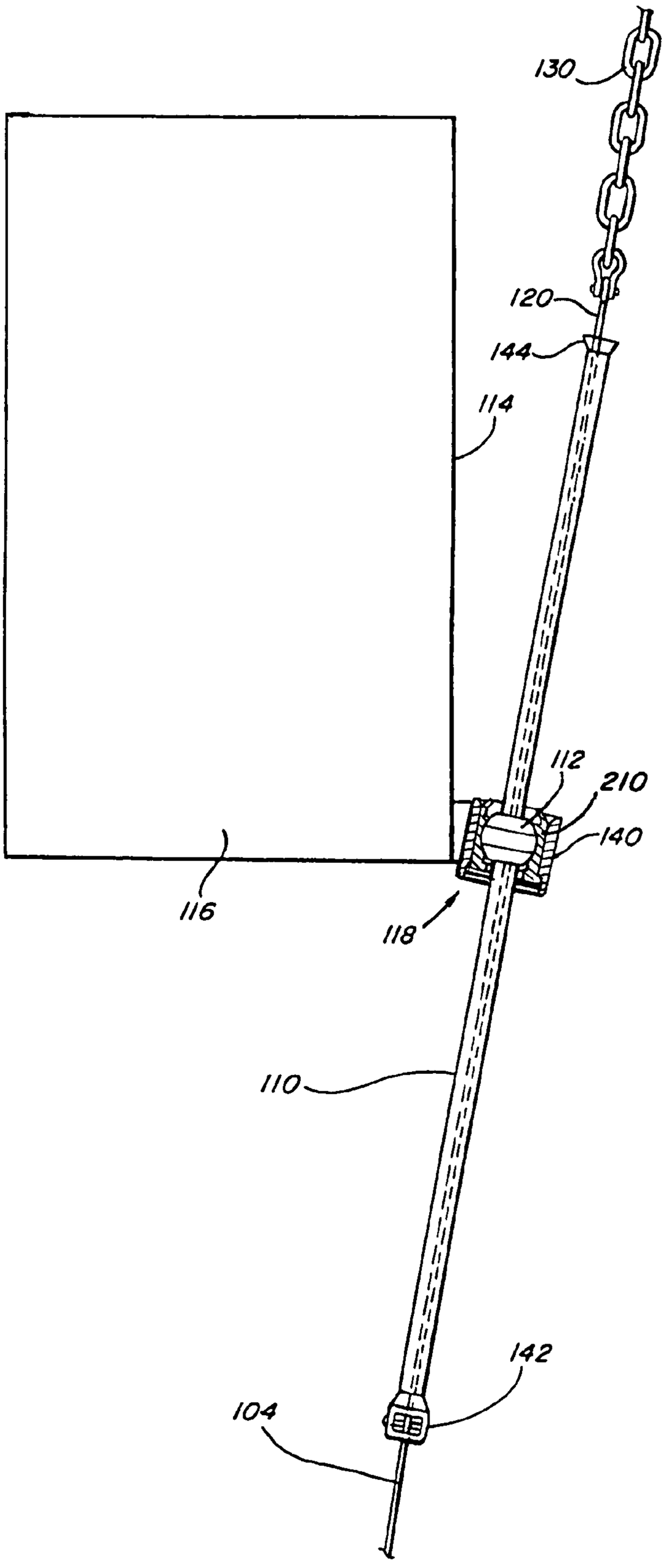

130
120
144
114
112
210
140
116
118
110
142
104

FIG. 5

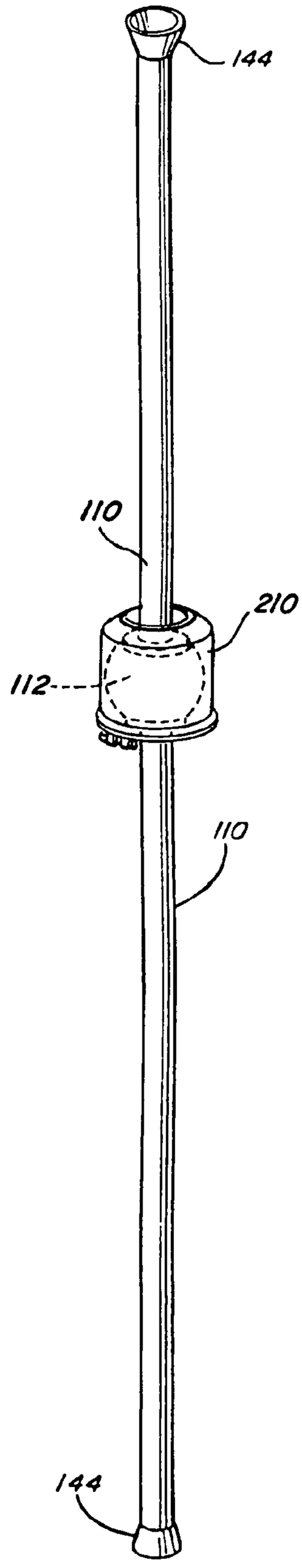
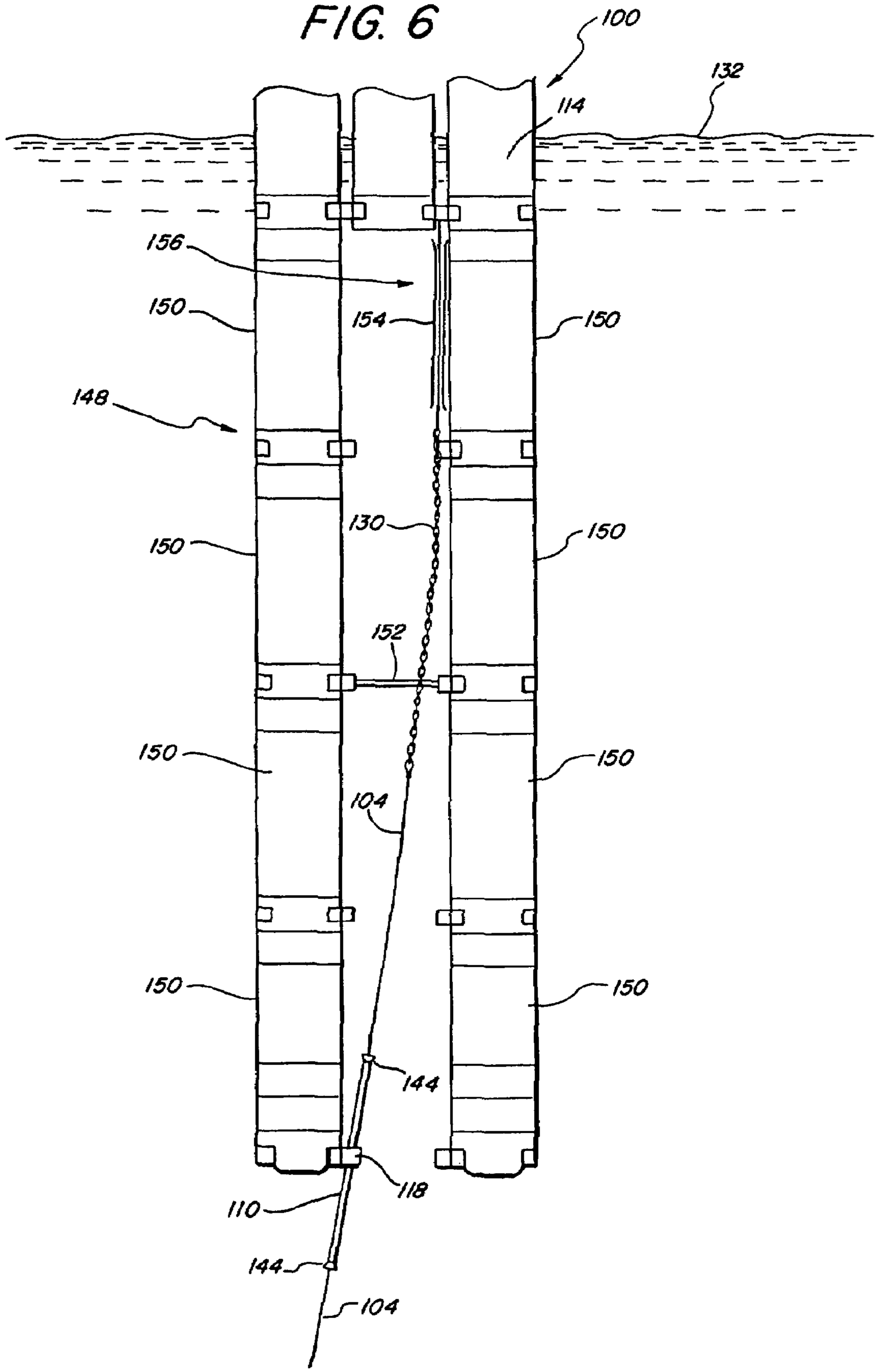

144
110
210
112
110
144

FIG. 6


100
132
114
156
150
154
150
148
150
130
150
152
150
150
104
150
150
144
118
110
144
104

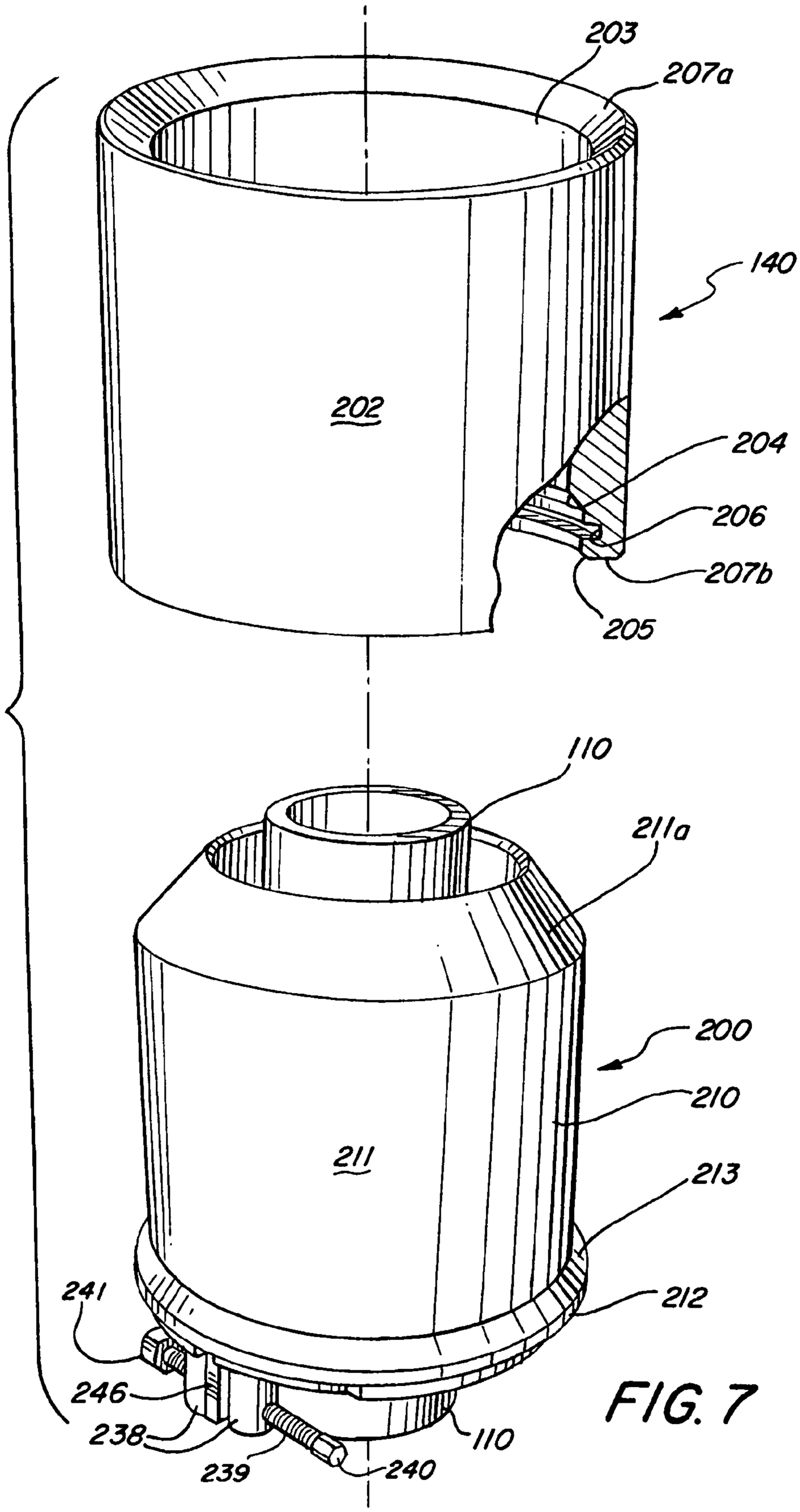

203
207a
140
202
204
206
207b
205
110
211a
200
210
211
213
212
241
246
238
239
240
110

FIG. 7

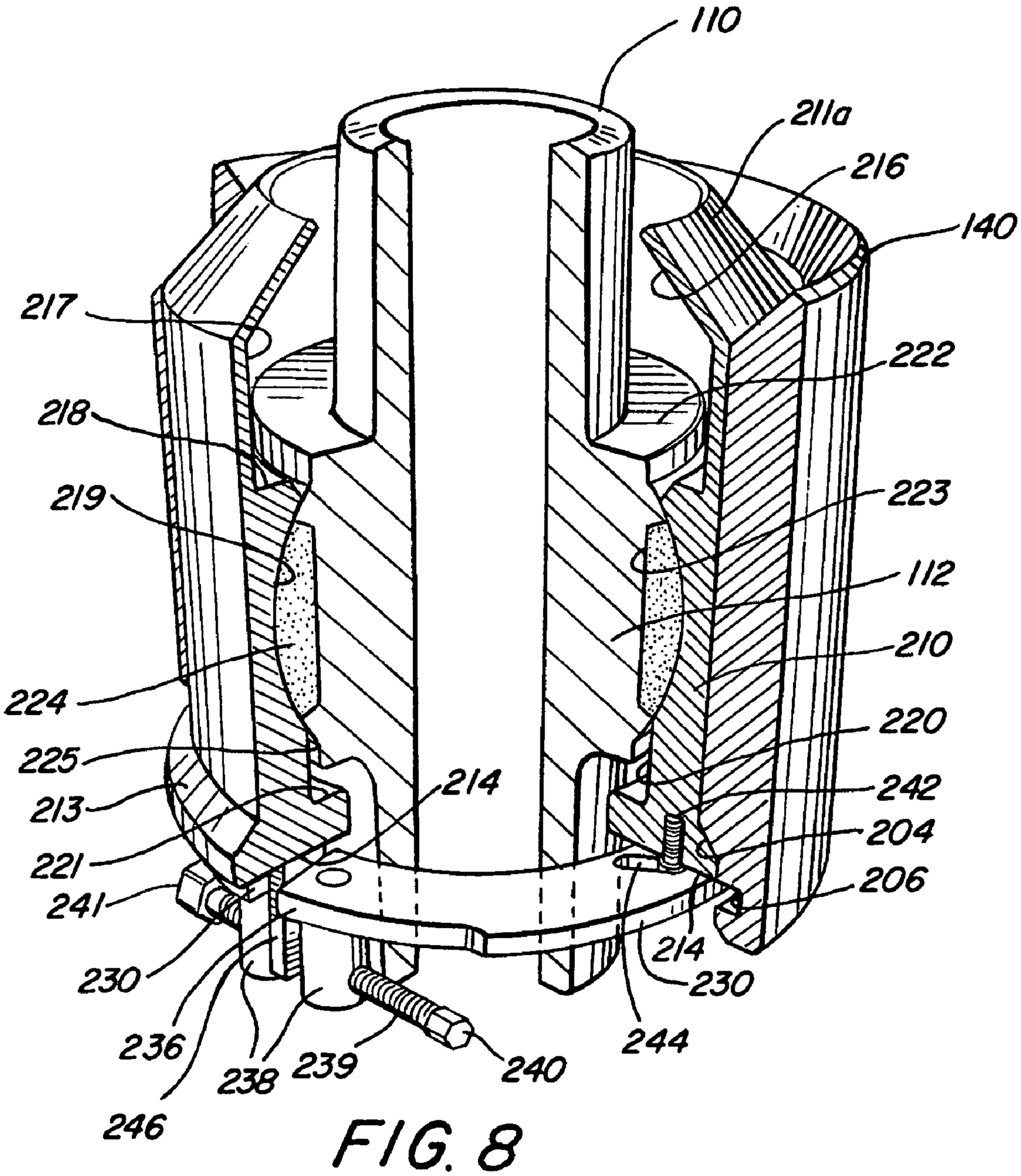

110
211a
216
140
217
222
218
219
223
112
210
224
220
225
214
213
242
221
204
241
206
214
230
230
236
238
239
240
244
246

FIG. 8

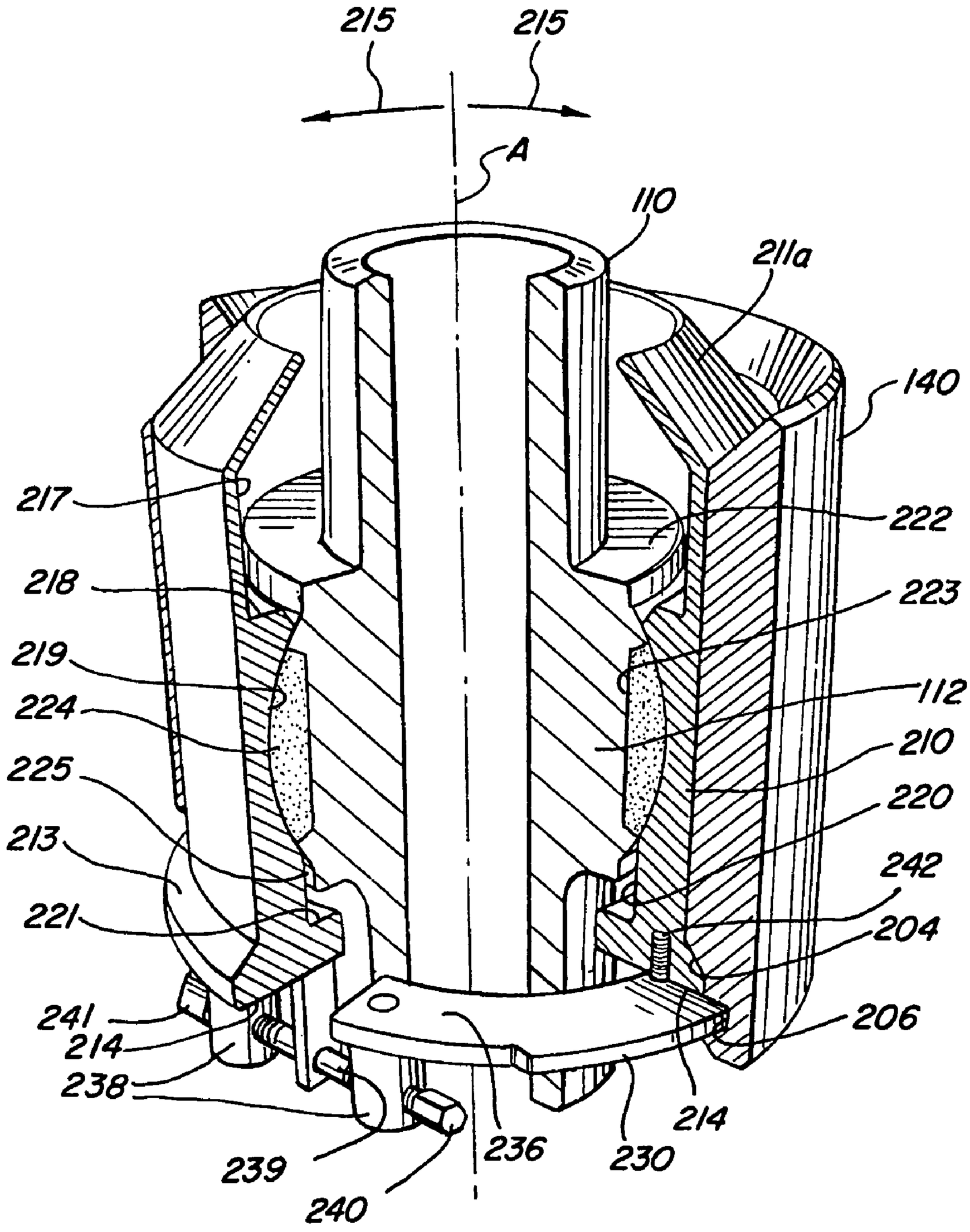

215
215
A
110
211a
140
217
222
218
223
219
112
224
210
225
220
213
242
221
204
241
206
214
238
214
239
236
230
240

FIG. 9

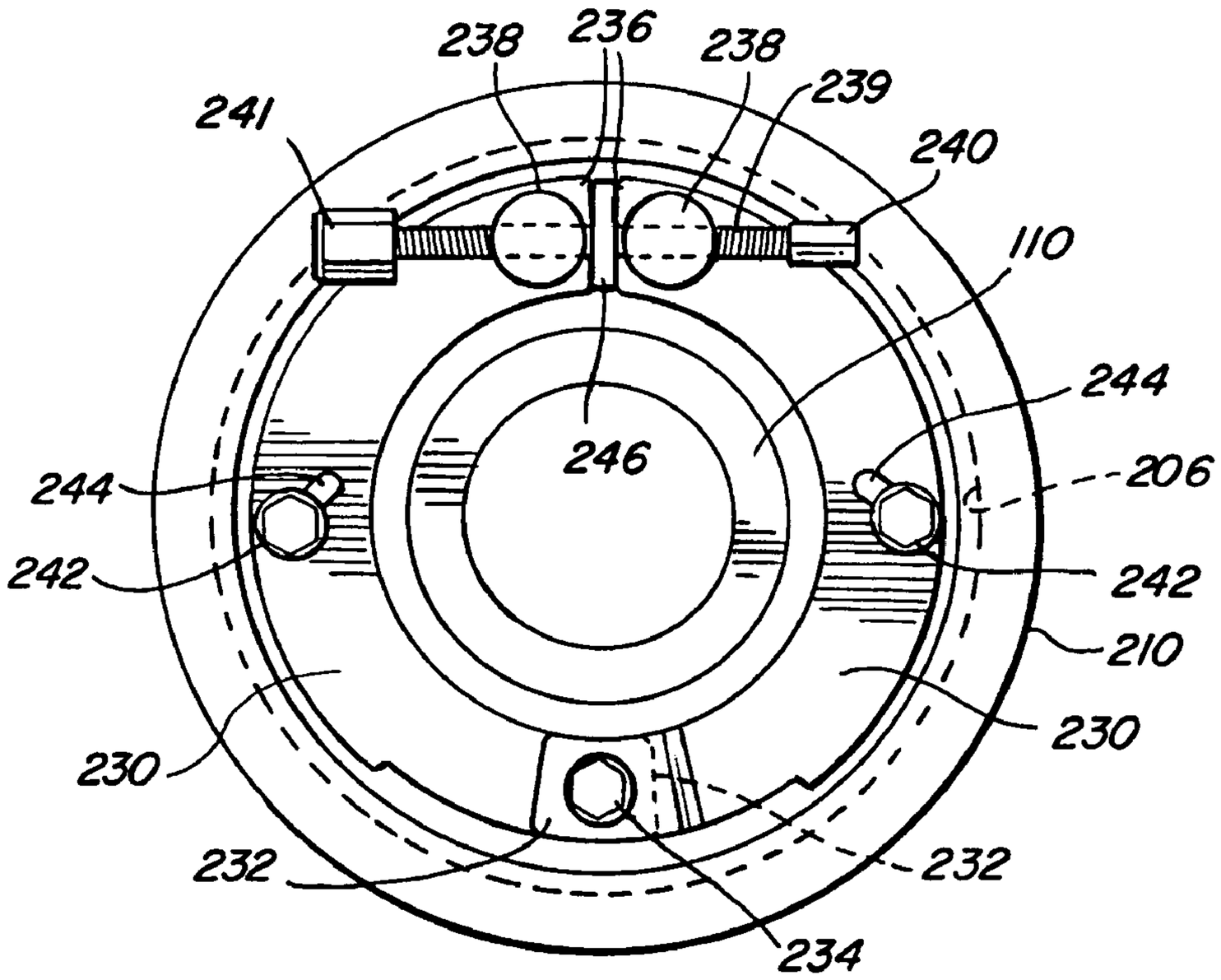

238
236
238
239
241
240
110
244
246
206
244
242
242
210
230
230
232
232
234

FIG. 10

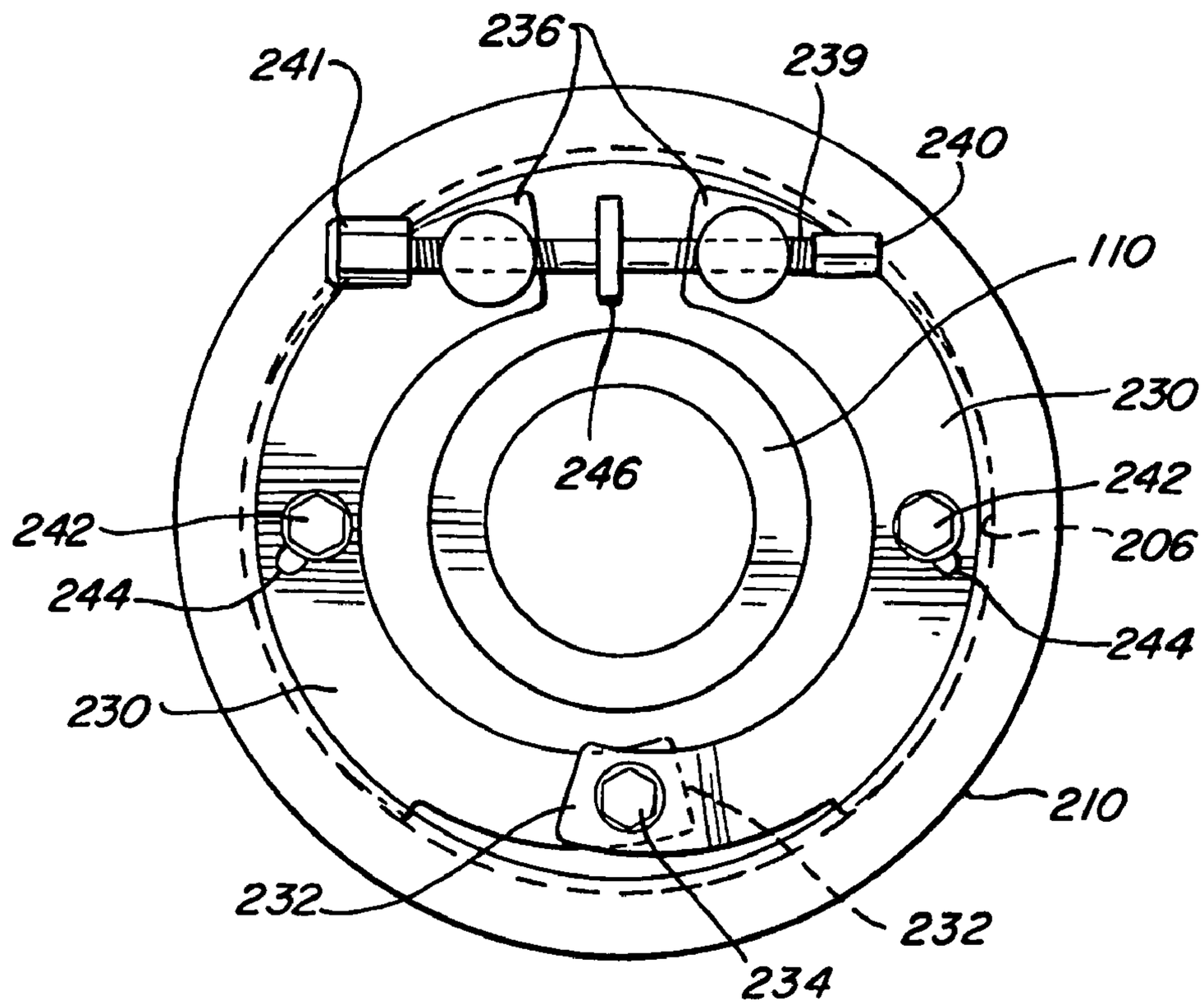

236
241
239
240
110
230
246
242
242
206
244
244
230
210
232
232
234

FIG. 11

APPARATUS AND METHOD FOR SUPPORTING A STEEL CATENARY RISER

CROSS-REFERENCE TO RELATED APPLICATION

Not Applicable

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

BACKGROUND OF THE INVENTION

The present invention relates to the field of offshore drilling and production structures. More specifically, it relates to an apparatus for a supporting a steel catenary riser (SCR) extending to the seabed from a floating offshore structure (e.g., a platform or a vessel).

Offshore platforms used for the production of petroleum and natural gas from seabed wells frequently include one or more production risers for the extraction from the well of the product (petroleum or natural gas) and/or for the injection into the well of a fluid (gas or water) to aid in the extraction of the product. One type of riser that is well known and that is commonly used is a flexible steel riser known as a steel catenary riser, or "SCR."

The current practice in riser systems is to provide a pull tube for installing and supporting a steel catenary riser. A support section of the pull tube keeps the stresses in the riser within allowable limits during installation and operation. One prior art example is shown in FIG. **1**, which represents an SCR support structure of the type shown in U.S. Pat. No. 5,722,492, the disclosure of which is incorporated herein by reference. A floating offshore structure **12** is held in position in a body of water **36** by mooring lines **14** that are secured to the seabed **16** by means such as anchors or pilings (not shown). An SCR **18** has a lower end attached to a wellhead (not shown) in the seabed **16**. A flexible support tube **22** supports the SCR **18** within the structure **12**. An upper portion **24** of the riser **18** extends up and through a center well **26** situated within the floating structure **12**, for attachment thereto at a location **28**.

The SCR **18** is pulled through the support tube **22** by pull-in rigging (not shown). The inside diameter of the support tube **22** must be large enough to allow the pull-in rigging to pass through it. As a result, the support tube **22** diameter is often considerably larger than the diameter of the SCR **18**, wherein the relatively large diameter of the support tube **22** relative to that of the SCR **18** gives the support tube **22** a high degree of stiffness relative to the stiffness of the SCR **18**. The high degree of stiffness of the support tube **22** (relative to the stiffness of the SCR **18**) results in a concentration of bending strain in the SCR **18** at the location where the SCR **18** exits the support tube **22**. This concentration of bending strain contributes to excessive stress and strain in the SCR **18**.

It would thus be advantageous to provide a catenary riser support system that does not require the use of large diameter risers and support tubes with a large stiffness relative to the stiffness of the riser.

SUMMARY OF THE INVENTION

In one aspect of the present invention, in accordance with a preferred embodiment thereof, an apparatus for supporting an SCR having an upper end secured to a floating structure and a lower end secured to the seabed comprises a flexible support tube or keel sleeve that encloses the SCR, and that contains a latching pivot mechanism that selectively locks the support tube or keel sleeve in a receptacle on the floating structure in a manner that allows the support tube or keel sleeve both to pivot relative to the floating structure, and to bend to achieve the desired SCR bend-limiting effect. The diameter of the support tube or keel sleeve is just great enough to allow passage of the riser, and therefore the stiffness of the support tube or keel sleeve is closely matched to that of the SCR. Some embodiments of the invention include a pull tube segment enclosing the riser at a location above the support tube or keel sleeve. The pull tube segment may be attached to the floating structure at one or more attachment points above the keel.

In another aspect of the present invention, in accordance with a preferred embodiment thereof, a method of installing and supporting an SCR on a floating structure comprises the steps of passing a first end of the SCR through the interior of a narrow, flexible support tube or keel sleeve until the first end of the SCR emerges from a top end of the support tube or keel sleeve; attaching a pull-in rigging to the first end of the SCR; fixing the support tube or keel sleeve to the SCR; pulling the SCR and the support tube or keel sleeve, by means of the pull-in rigging, up through a pivot linkage receptacle attached to the floating structure; latching the support tube or keel sleeve in the pivot linkage receptacle; releasing the support tube or keel sleeve from the SCR; and pulling the SCR up through the support tube or keel sleeve to connect the first end of the SCR to the floating structure. In those embodiments employing both a keel sleeve and a pull tube enclosing the SCR at a location above the keel, the method includes the step of fixing a pull tube to the floating structure at a location above the keel, and the step of pulling the SCR through the keel sleeve to connect the first end of the SCR to the floating structure includes the step of passing the SCR through the pull tube before the first end thereof is connected to the structure.

In a preferred embodiment of the invention, the latching pivot mechanism comprises a ball joint pivot mechanism contained in a barrel or housing that fits into the pivot linkage receptacle, and a latching mechanism that is selectively operable to lock the latching pivot mechanism in place within the receptacle. The latching mechanism advantageously comprises a pair of latching plates that are pivotably secured to the bottom of the housing, and that are operable to move from a first position in which they are disengaged from the receptacle, to a second position in which they are in locking engagement with the receptacle.

The various aspects and advantages of the present invention summarized above will be more completely understood with reference to the following detailed description of the preferred embodiments thereof, in connection with the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view of a floating offshore structure, as described above, on which a prior art steel catenary riser (SCR) support system has been installed;

FIG. **2** is an idealized, simplified view of the process of installing an SCR support system, in accordance with a first preferred embodiment of the present invention, on an extendable draft platform (EDP);

FIG. **3** is an idealized, simplified view of an EDP, as shown in FIG. **2**, with the SCR support system of the present invention installed thereon;

FIG. **4** is a detailed view of the riser support system in accordance with the present invention, after the keel sleeve has been installed in a pivot linkage attached to the keel of a floating structure, but before the SCR has been pulled through the keel sleeve for attachment to the floating structure;

FIG. **5** is a perspective view of a keel sleeve of the type employed in the SCR support system of the present invention:

FIG. **6** is an idealized, simplified view of a spar-type platform on which an SCR support system in accordance with a second preferred embodiment of the present invention has been installed;

FIG. **7** is an exploded perspective view of an exemplary pivot linkage receptacle and a latching ball joint pivot mechanism employed in the present invention;

FIG. **8** is a partially cut-away perspective view of the pivot linkage receptacle and the latching ball joint pivot mechanism of FIG. **7**, showing the pivot mechanism received in the receptacle in an unlatched position;

FIG. **9** is a partially cut-away perspective view of the pivot linkage receptacle and latching pivot mechanism of FIG. **7**, showing the pivot mechanism received in the receptacle in a latched position;

FIG. **10** is a bottom plan view of the pivot linkage receptacle and latching pivot mechanism of FIG. **7**, showing the pivot mechanism received in the receptacle in an unlatched position; and

FIG. **11** is a bottom plan view of the pivot linkage receptacle and latching pivot mechanism of FIG. **7**, showing the pivot mechanism received in the receptacle in a latched position.

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides support for a steel catenary riser (SCR) by enclosing the riser within a support tube (such as a bending limiting pipe section or a keel sleeve) and attaching the support tube to the keel of a floating structure. The support tube includes a latching pivot linkage mechanism, and it is supported within a riser guide receptacle that receives the pivot linkage mechanism to accommodate angle changes sustained by the riser as the floating structure changes position due to conditions such as tides, waves, currents, winds, and the like.

FIG. **2** shows a floating structure embodied as an extendable draft platform (EDP) **100** floating on the surface **132** of a body of water. The EDP **100** typically includes a deck **108** supported above the surface **132** by a plurality of buoyant columns **114**, the bottom portions of which may be defined as a keel **116**. Although the following description refers to an EDP **100**, it is to be understood that the present description also applies to any suitable type of floating structure, such as a floating platform, spar, boat, ship, production barge, FPSO (floating production, storage, and offloading structure), and the like.

In accordance with a preferred embodiment of the present invention, an SCR **104** extends from a lower end (not shown) connected to a wellhead (not shown) on the sea floor, to an upper end connected to a yoke **106** operationally connected to the deck **108** of the EDP **100**. The SCR **104** is a flexible conduit that is typically formed of a plurality of interconnecting metal (such as steel) tubing or pipe segments axially connected together, as is well-known in the art. The SCR **104** is enclosed within a bending limiting pipe section **110**, such as a support tube or a keel sleeve, to be described in more detail below. The support tube or keel sleeve **110** includes a latching pivot mechanism (described below) that advantageously includes a pivot ball **112**. A riser guide **118** is fixed to the keel **116** of the EDP **100**, and it includes a pivot linkage receptacle (described below) that receives the support tube or keel sleeve **110**.

In accordance with a preferred embodiment of the method of the present invention, the SCR **104** may be installed by extending it between the EDP **100** and the seabed (not shown). A method of installation, in accordance with the present invention, comprises a first step of inserting a first end **120** of the SCR **104** into the bottom end of the support tube or keel sleeve **110**, and then pulling the SCR **104** through the keel support tube or keel sleeve **110** until the first end **120** of the SCR **104** emerges from the top end of the support tube or keel sleeve **110**. The SCR **104** may then be temporarily secured to the support tube or keel sleeve **110** by means of a clamp **142** (see FIG. **4**) on the bottom end of the support tube or keel sleeve. These steps may be performed while the support tube or keel sleeve **110** is onboard a service vessel **122**. The SCR **104** is then lowered from the service vessel **122** to a point below the keel **116** of the EDP **100**. A winch **126** on the vessel **122** may be used to raise and lower the SCR **104** via a pull cable **128** secured to a pull-in rigging **130** attached to the first end **120** of the SCR **104**.

Next, by means such as a cable or pull line **133**, the SCR **104** is pulled, with the support tube or keel sleeve **110**, up through a receptacle (described below) in the riser guide **118** fixed to the keel **116** of the EDP **100**. The installation may be furthered by releasing the clamp **142** and pulling the SCR **104** through the support tube or keel sleeve **110** up to the deck **108** of the EDP **100**. The SCR **104** is then secured, at the yoke **106**, to the EDP **100**. The support tube or keel sleeve **110** may then be secured again to the SCR **104** by means of the clamp **142**. Thus, as shown in FIG. **3**, upon completion of the installation of the SCR **104** in accordance with the present invention, the support tube or keel sleeve **110** is secured within the riser guide **118** and the SCR **104** is attached to the deck **108** of the EDP **100**.

FIG. **4** shows a detailed view of the SCR **104** contained in a support tube or keel sleeve **110** attached to the keel **116** of the EDP **100**. As noted above, the support tube or keel sleeve **110** is secured to the keel **116** by a pivot linkage receptacle **140** within the riser guide **118**. As discussed on detail below, the pivot linkage receptacle **140** receives the latching pivot mechanism (to be described below) so as to permit the SCR **104** and the support tube or keel sleeve **110** to pivot to relieve stress. The SCR **104** may be axially fixed relative to support tube or keel sleeve by a releasable clamp **142**, to maintain the support tube or keel sleeve **110** near an upper end of the SCR **104** for installation in the desired position.

As shown in detail in FIG. **5**, the support tube or keel sleeve **110** is preferably formed as a tubular length of a flexible steel or other suitable flexible material, and it preferably is formed with flared ends **144**, as shown. The support tube or keel sleeve **110** is designed to be flexible, so that it can bend with the SCR **104** that passes through it. The pivot ball **112**, which is advantageously located near the mid-point along the length of the tube or sleeve **110**, is contained within a tubular housing or barrel **210** that is a part of a latching pivot mechanism, described in detail below. The inside diameter of the tube or sleeve **110** is (except for the flared ends **144** and the pivot ball **112**) only slightly larger than the outside diameter of the SCR **104**, and thus it is advantageously smaller than the diameter of the pull-in rigging **130**, as shown in FIG. **4**. Thus, the tube or sleeve **110** may be made with a stiffness that is approximately equal to, or at least does not greatly exceed, that of the SCR **104**.

FIG. **6** shows an embodiment of the riser support system of the present invention for supporting an SCR **104** from a

spar-type floating platform **100'**, which has a hull **148** comprising a plurality of cells **150** interconnected end to end, as is well-known in the art. At least one lateral support bar **152** may be used to support the hull **148** and to limit lateral movement of the SCR **104**. A flexible pull tube **154** encloses the SCR **104** and is fixed to the hull **148** at a location **156** above the keel sleeve or support tube **110**. The pull tube **154** further limits stresses in the SCR **104**.

FIGS. **7-11** show a preferred embodiment of a pivot linkage receptacle **140**, adapted and configured for attachment to the keel of a floating structure, and a latching ball joint pivot mechanism **200** that is configured to be latched into the receptacle **140**. The latching ball joint pivot mechanism **200** comprises, in terms of its major components, a tubular housing or barrel **210**, the pivot ball **112** of the support tube or keel sleeve **110**, and a pair of arcuate latching plates **230** that are located on the bottom surface of the barrel **210** and that are movable between a latched position and an unlatched position relative to the receptacle **140**, as discussed below.

As best shown in FIG. **7**, the pivot linkage receptacle **140** is generally of tubular construction, having an exterior surface **202** of substantially uniform or constant diameter, and a main interior surface defining a bore **203**. The interior surface has an outwardly-tapered shoulder **204** near the lower end thereof. The shoulder **204** connects the main interior surface **203** with an enlarged-diameter lower end interior surface portion **205**, in which an annular latching groove **206** is formed. The exterior surface **202** of the pivot linkage receptacle **140** may be welded or attached by other means to the keel **116**, or to the riser guide **118**. The exterior surface **202** and the interior surface **203** may be joined by annular oblique and/or transverse surfaces **207***a*, **207***b* at the top and bottom, respectively. Preferably, at least part of the surfaces adjacent to the bore **203** of the receptacle **140** will be inclined inward, providing easy entry for the support tube or keel sleeve **110** with the ball joint pivot mechanism **200**.

The barrel **210** of the pivot mechanism has a generally cylindrical exterior surface **211** with a frustoconical upper portion **211***a*, and an annular flange **212** near the lower end thereof. The flange **212** has a tapered upper surface **213** that mates with the tapered shoulder **204** of the receptacle when the barrel **210** is inserted into the receptacle, so that the mating surfaces **204**, **213** function as stop surfaces to position the barrel **210** axially within the receptacle **140** for proper functioning of the latching mechanism, as will be described below. The flange **212** of the barrel **210** has a flat, annular bottom surface **214**.

As shown in FIGS. **8** and **9**, sequentially from the upper end of the barrel **210**, the interior bore of the barrel **210** includes an inwardly-tapered upper interior surface **216**, an upper cylindrical surface **217**, an inwardly-directed annular upper shoulder **218**, a concave ball joint surface **219**, a lower cylindrical interior surface **220**, and an inwardly-directed annular lower shoulder **221**. The outside diameter of the exterior barrel surface **211** should be slightly smaller than the inside diameter of the pivot linkage receptacle **140** to allow the barrel **210** to slide into the bore **203** of the receptacle **140**. The dimensions of the barrel flange **212** and the barrel outer cylindrical surface **211** should be also slightly smaller than the corresponding receptacle shoulder **204** and the cylindrical lower end surface portion **205**, so that the barrel **210** may fit into the bore **203** of the pivot linkage receptacle **140**.

As shown in FIGS. **8** and **9**, the flexible keel sleeve or support tube **110** has an annular joint flange **222** just above the pivot ball **112**. The flange **222** is positioned to be received in the bore of the barrel **210** above the upper interior shoulder **217** of the barrel **210**. The pivot ball **112** may advantageously be formed with an annular recess or pocket **223** in which is installed a low-friction anti-galling material **224**, such as, for example, an aluminum-bronze bearing alloy, thereby providing a low friction pivot bearing surface that seats against the concave ball joint surface **219** in the bore of the barrel **210**. Thus, the pivot ball **112** and the concave ball joint surface **219** form a pivoting ball joint that allows the support tube or sleeve **110** to pivot relative to the axis A of the barrel **210**, as indicated by the arrows **215** in FIG. **9**. Angular travel of the support tube or sleeve **110** in pivoting is limited by an annular stop surface **225** on the tube or sleeve **110** below the ball **112**, which stop surface abuts against the lower cylindrical surface **220** in the bore of the barrel **210** at the limits of travel of the sleeve or tube **110**.

As best shown in FIGS. **10** and **11**, the latching mechanism comprises first and second latching elements that, in the preferred embodiment, are in the form of arcuate (i.e., approximately semicircular) latching plates **230**, each of which has a first end **232** that is pivotally connected to the first end of the other plate by a pivot bolt **234** that is threaded into the flat bottom surface **214** of the barrel bottom flange **212**. Each of the plates **230** has a second end **236** that is opposed to and separated from the second end of the other plate by a gap, the width of which is varied, as described below, as the plates are pivoted about an axis defined by the pivot bolt **234**.

As shown in FIGS. **7-11**, a transversely-threaded post **238** extends downwardly from the second end **236** of each of the latching plates **230**. A latching bolt **239**, the purpose and operation which will be described below, is threaded through the posts **238**. The latching bolt **239** has a first end terminating in a hex-head **240** configured to receive a socket wrench or like implement (not shown) that may be employed by an ROV (not shown) to turn the latching bolt **239**, as discussed below. The opposite end of the latching bolt **239** terminates in an upset **241** that forms a stop element to limit the movement of the posts **238**, as discussed below.

In a preferred embodiment of the invention, the latching bolt **239** has a first portion, adjacent the hex head end **240**, that is threaded in a first direction, i.e., a right-hand thread, and a second portion, adjacent the upset end **241**, that is threaded in the opposite direction (i.e., a left-hand thread). The respective posts **238** are threaded to accommodate the portion of the latching bolt **239** that is threaded into that post. Thus, the post **238** through which the right-hand threaded portion of the latching bolt **239** is threaded likewise is right-hand threaded, while the post **238** through which the left-hand threaded portion of the latching bolt **239** is threaded likewise is left-hand threaded. Between the threaded first and second portions of the latching bolt **239** is an intermediate portion that is smooth (not threaded). The smooth portion of the latching bolt **239** is journaled in a retention element **246** that extends downward from the flat bottom surface **214** of the barrel bottom flange **212** between the posts **238**, as best shown in FIGS. **10** and **11**.

Each of the latching plates **230** is seated on, and movably secured to, the flat bottom surface **214** of the barrel bottom flange **212** by a plate bolt **242** that is threaded into the flat bottom surface **214** of the barrel bottom flange **212** through an elongate slot **244** in the respective plate **230**. The combination of the pivoting provided by the pivot bolt **234** and the "play" or movement allowed by the elongate slots **244** allows the latching plates **230** to move from a radially withdrawn or "unlocked" position (FIGS. **8** and **10**) to a radially extended or "locked" position (FIGS. **9** and **11**) in response to the rotation of the latching bolt **239** and the resultant movement of the posts **238** along the length of the latching bolt **239**. The posts **238** and the latching bolt **239** thus serve as a latching plate

actuation mechanism for moving the latching plates **230** fro a first (unlocked) position to a second (locked) position. Specifically, when the latching bolt **239** is rotated at its hex head end **240** in a first direction (i.e., clockwise), the post **238** in which the first portion of the latching bolt **239** is threaded moves toward hex head end **240**, while, because of the reverse threading on the second portion of the latching bolt **239** and in its associated post **238**, the post **238** in which the second portion of the latching bolt **239** is threaded moves toward the upset end **241** of the bolt **239**. Thus, the two posts **238**, and their respective second ends **236** of the latching plates **230**, are moved farther apart to pivot the plates **230** into their locked position.

The movement of the plates **230** is reversed when the latching bolt **239** is rotated in the opposite direction (i.e., counter-clockwise) at its hex head end **240**, the post **238** in which the first portion of the latching bolt **239** is threaded moves toward the center of the latching bolt **239**, as does the post **238** through which the second portion of the latching bolt **239** is threaded, both posts **238** ceasing their travel toward the center of the latching bolt **239** (and toward each other) when they encounter the unthreaded intermediate portion of the latching bolt **239**. Thus, as the posts **238** travel along the latching bolt **239** toward each other, they urge their respective second ends **236** of the latching plates **230** are urged closer together, causing the plates **230** to pivot toward their unlocked position.

When the barrel **210** of the pivot mechanism **200** is properly seated within the receptacle **140**, as described above, the plates **230** are axially located within the receptacle **140** so as to coincide with the annular latching groove **206**. When the barrel **210** is inserted into the receptacle **140**, the latching plates **230** are in their withdrawn position (FIGS. **8** and **10**) allowing the barrel **210** to be inserted into the receptacle **140**. The insertion of the barrel **210** proceeds until the stop surface **213** of the barrel abuts the mating stop surface **204** of the receptacle, at which point the latching plates **230** are properly aligned with the latching groove **206** in the barrel. The pivot mechanism **200** is then latched into the receptacle **140** by turning the latching bolt **239** at its hex head end **240** (by means of, for example, an ROV, not shown) in the first direction, as described above, whereby the latching plates **230** are pivoted to their extended or locked position (FIGS. **9** and **11**), in which they are received in the latching groove **206**.

Although the present invention has been described with reference to specific embodiments, these embodiments are illustrative only and not limiting. Specifically, various modifications and variations of the present invention will suggest themselves to those skilled in the pertinent arts, such as, for example, variations in the specific order of the method steps described herein, and, as suggested above, in the specific structure of the latching pivot mechanism described herein and illustrated in the drawings. These variations and modifications, as well as others that might suggest themselves from this disclosure, are considered within the spirit and scope of the present invention, as defined in the claims that follow.

What is claimed is:

1. Apparatus for supporting a steel catenary riser (SCR) on a floating structure, comprising:

a receptacle attached to the floating structure;

a flexible support tube enclosing the SCR and dimensioned so as to support the SCR while allowing the SCR to bend; and

a pivoting mechanism on the support tube that secures the support tube in the receptacle in a manner that allows the support tube to pivot relative to the floating structure, wherein the pivoting mechanism includes a latching mechanism that is operable selectively to latch the pivoting mechanism within the receptacle.

2. The apparatus of claim **1**, wherein the floating structure includes a keel, wherein the receptacle is attached to the keel, wherein the support tube is a keel sleeve, and wherein the apparatus further comprises a pull tube segment enclosing the riser at a location above the keel sleeve, wherein the pull tube segment is attached to the floating structure above the keel sleeve.

3. The apparatus of claim **1**, wherein the pivoting mechanism comprises:

a barrel dimensioned to fit inside the receptacle; and

a ball pivot mounted within the barrel so as to be pivotable relative to the barrel.

4. The apparatus of claim **3**, further comprising a latching mechanism, operably associated with the barrel, and operable selectively to latch the barrel within the receptacle.

5. The apparatus of claim **4**, wherein the barrel has a bottom surface, and wherein the latching mechanism comprises:

a pair of latching elements mounted on the bottom surface of barrel so as to be movable between a first position that is out of engagement with the interior of the receptacle and a second position that is in a locking engagement with the interior of the receptacle when the barrel is positioned within the receptacle; and

a latching element actuation mechanism operable on the latching elements so as to move them between the first position and the second position.

6. The apparatus of claim **5**, wherein each of the latching elements is a plate that is pivotable between a radially withdrawn position and a radially extended position in response to the latching element actuation mechanism.

7. An apparatus for supporting a steel catenary riser (SCR) on a floating structure having a keel, comprising:

a flexible keel sleeve enclosing a portion of the length of the SCR;

a pivot mechanism on the keel sleeve; and

a pivot linkage receptacle attached to the keel of the floating structure and internally dimensioned to receive the pivot mechanism;

wherein the pivot mechanism secures the keel sleeve within the receptacle in a manner that allows the keel sleeve to pivot relative to the floating structure, and wherein the pivot mechanism comprises a latching mechanism operable to lock the pivot mechanism into the receptacle.

8. The apparatus of claim **7**, wherein the receptacle includes an internal groove, and wherein the latching mechanism includes a pair of latching elements that are movable between an unlocked position in which they are not seated in the groove, and a locked position in which they are seated in the groove.

9. The apparatus of claim **8**, wherein the pivot mechanism includes a barrel having a bottom surface, wherein the barrel is dimensioned to be received d in the receptacle, and wherein each of the latching elements comprises a latching plate having has a first end pivotally attached to the bottom surface, and a second end that is spaced from the second end of the other latching element, whereby the latching plates are movable from the unlocked position to the locked position by pivoting so as to increase the distance between their respective ends.

10. The apparatus of claim **9**, wherein the latching mechanism further comprises a latching bolt operably coupled to the latching plates so that, when the bolt is rotated in a first direction, it moves the plates from the unlocked position to

the locked position, and when the bolt is rotated in a second direction, it moves the plates from the locked position to the unlocked position.

11. The apparatus of claim **7**, wherein the pivot mechanism comprises a ball joint pivot.

12. A method of supporting a steel catenary riser (SCR) from a floating structure, comprising the steps of:

providing a flexible support tube comprising a pivot linkage that includes a latching mechanism;

passing a first end of the SCR through the interior of the flexible support tube until the first end of the SCR emerges from a top end of the support tube;

attaching a pull-in rigging to the first end of the SCR;

fixing the support tube to the SCR;

pulling the SCR and the support tube, by means of the pull-in rigging, up through a receptacle attached to the floating structure;

securing the support tube in the receptacle by inserting the pivot linkage into to the receptacle and then operating the latching mechanism to latch the pivot linkage within the receptacle;

releasing the support tube from the SCR;

pulling the SCR up through the support tube; and

connecting the first end of the SCR to the floating structure.

13. The method of claim **12**, comprising the further step, after the step of pulling the SCR through the support tube, of again fixing the support tube to the SCR.

14. The method of claim **12**, further comprising the step of fixing a pull tube to the floating structure at a location above the keel, and wherein the step of pulling the SCR through the support tube includes the step of passing the SCR through the pull tube before the first end thereof is connected to the structure.

15. The method of claim **12**, wherein the floating structure has a keel, and wherein the receptacle is attached to the keel.

16. The method of claim **12**, wherein the step of operating the latching mechanism is performed by a remotely-operated vehicle (ROV).

17. Apparatus for supporting a steel catenary riser (SCR) on a floating structure, comprising:

a receptacle attached to the floating structure;

a flexible support tube enclosing the SCR and dimensioned so as to support the SCR while allowing the SCR to bend; and

a pivoting mechanism on the support tube that secures the support tube in the receptacle in a manner that allows the support tube to pivot relative to the floating structure, wherein the pivoting mechanism comprises:

a barrel dimensioned to fit ii side the receptacle;

a ball pivot mounted within the barrel so as to be pivotable relative to the barrel; and

a latching mechanism, operably associated with the barrel, and operable selectively to latch the barrel within the receptacle.

18. The apparatus of claim **17**, wherein the floating structure includes a keel, wherein the receptacle is attached to the keel, wherein the support tube is a keel sleeve, and wherein the apparatus further comprises pull tube segment enclosing the riser at a location above he keel sleeve, wherein the pull tube segment is attached to the floating structure above the keel sleeve.

19. The apparatus of claim **17**, wherein the barrel has a bottom surface, and wherein the latching mechanism comprises:

a pair of latching elements mounted on the bottom surface of barrel so as to be movable between a first position that is out of engagement with the interior of the receptacle and a second position that is in a locking engagement with the interior of the receptacle when the barrel is positioned within the receptacle; and

a latching element actuation mechanism operable on the latching elements so as to move them between the first position and the second position.

20. The apparatus of claim **19**, wherein each of the latching elements is a plate that is pivotable between a radially withdrawn position and a radially extended position in response to the latching element actuation on mechanism.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,467,914 B2
APPLICATION NO. : 11/225148
DATED : December 23, 2008
INVENTOR(S) : Lyle Finn and Gerald Crotwell

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

The punctuation ":" in column 3, line 7 should read as --;--

The word "fro" in column 7, line 1 should read as --from--

The word "has" in column 8, line 59 should be deleted

The letter --a-- needs to be inserted between "comprises" and "pull" in column 10, line 18

The word "he" in column 10, line 19 should read as --the--

The word "on" in column 10, line 38 should be deleted

Signed and Sealed this

Third Day of March, 2009

JOHN DOLL
Acting Director of the United States Patent and Trademark Office